TOTAL DISSOLVED SOLIDS

FACT SHEET

See related Fact Sheets: Acronyms & Abbreviations; Glossary of Terms; Cost Assumptions; Raw Water Composition; Total Plant Costs; and WaTER Program.

1. CONTAMINANT DATA

A. Chemical Data: Total dissolved solids (TDS) or filterable residue are all of the dissolved solids in a water. TDS is measured on a sample of water that has been passed through a very fine filter (usually 0.45 micron) to remove the suspended solids. The water passing through the filter is evaporated (usually 103-105ºC) and the residue represents the TDS concentration (in mg/L). TDS is usually comprised of inorganic minerals (salts), small amounts of organic material, and can include small amounts of soluble minerals (Fe and Mn). A conductivity test of water provides only an estimate of TDS, as conductivity is not directly proportional to the weight of an ion, and non-conductive substances cannot be measured by electrical tests.

B. Source in Nature: Inorganic minerals (salts) are commonly found in nature, consisting of positive ions (sodium and calcium) bonded to negative ions (chloride and carbonate). The inorganic mineral compounds, and small amounts of minerals that comprise TDS, are soluble in water, and are deposited by the weathering of the sedimentary rocks and erosion of the earth's surface. Organic material is also naturally occurring in nature, as a result of decaying organisms, plants, and animals. Those organic materials in TDS are also water soluble. Higher concentrations of TDS may occur during and after precipitation events.

C. SDWA Limits: SMCL for TDS is 500 mg/L.

D. Health Effects of Contamination: As a secondary drinking water contaminant, TDS does not pose any health risks. Secondary standards refer to those contaminants which cause aesthetic problems. The inorganic minerals and organic material, and small amounts of soluble minerals, in TDS have no notable ill health effects. Na_2SO_4 concentrations above 250 mg/L may produce a laxative effect. Excess sodium may affect those restricted to low sodium diets or pregnant women suffering from toxemia. High levels of TDS may present an objectionable taste, odor, and color to drinking water. Other aesthetic concerns include an indicator of corrosivity, scaling, and limiting the effectiveness of detergents.

2. REMOVAL TECHNIQUES

A. USEPA BAT: As a secondary drinking water contaminant, BATs are not assigned.
B. Alternative Methods of Treatment: The most common treatment processes for removing TDS are reverse osmosis and electrodialysis.

! RO uses a semipermeable membrane, and the application of pressure to a concentrated solution which causes water, but not suspended or most dissolved solids, to pass through the membrane. Benefits: produces high quality water. Limitations: cost; pretreatment/feed pump requirements; concentrate disposal.

! EDR uses semipermeable membranes in which ions migrate through the membrane from a less concentrated to a more concentrated solution as a result of the ions' representative attractions to direct electric current. Benefits: contaminant specific removal. Limitations: electrical requirements; concentrate disposal.

! Freezing and distillation can be used for higher concentrations of TDS, as found in sea water or brackish water (<3000 mg/L); and ion exchange can also be used, but has limited effectiveness in concentrations <3000 mg/L.

C. Related WTTP Publications:
1) WTTP Report #6, "Preliminary Research Study of a Water Desalination System for the East Montana Area Subdivisions of El Paso County, El Paso, Texas." This report summarizes the field study performed to determine the economics of several water treatment processes, including RO, ED, and multistage flash distillation, on brackish groundwater; concluded RO with surface water reject disposal was the most economical for the study area.
2) WTTP Report #15, "Maricopa Groundwater Treatment Study." This report summarizes the field study performed to determine the suitability of several water treatment processes, including RO, ED, and NF, on groundwater containing high levels of nitrate, chloride, and TDS; recommends the use of NF or ED for study area.

D. Safety and Health Requirements for Treatment Processes: Personnel involved with demineralization treatment processes should be aware of the chemicals being used (MSDS information), the electrical shock hazards, and the hydraulic pressures required to operate the equipment. General industry safety, health, and self protection practices should be followed, including proper use of tools.

3. BAT PROCESS DESCRIPTION AND COST DATA

General Assumptions: Refer to: Raw Water Composition Fact Sheet for ionic concentrations; and Cost Assumptions Fact Sheet for cost index data and process assumptions. All costs are based on *ENR*, PPI, and BLS cost indices for March 2001. General sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal are not included.

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3A. Reverse Osmosis:

Process - RO is a physical process in which contaminants are removed by applying pressure on the feed water to direct it through a semipermeable membrane. The process is the "reverse" of natural osmosis (water diffusion from dilute to concentrated through a semipermeable membrane to equalize ion concentration) as a result of the applied pressure to the concentrated side of the membrane, which overcomes the natural osmotic pressure. RO membranes reject ions based on size and electrical charge. The raw water is typically called feed; the product water is called permeate; and the concentrated reject is called concentrate. Common RO membrane materials include asymmetric cellulose acetate or polyamide thin film composite. Common membrane construction includes spiral wound or hollow fine fiber. Each material and construction method has specific benefits and limitations depending upon the raw water characteristics and pretreatment. A typical large RO installation includes a high pressure feed pump, parallel 1st and 2nd stage membrane elements (in pressure vessels); valving; and feed, permeate, and concentrate piping. Factors influencing membrane selection are cost, recovery, rejection, raw water characteristics, and pretreatment. Recent membrane improvements by manufacturers have produced nanofiltration (NF) membranes that are less costly to purchase and operate.

Pretreatment - RO requires a careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling, or other membrane degradation. Removal of suspended solids is necessary to prevent colloidal and bio-fouling, and removal of dissolved solids is necessary to prevent scaling and chemical attack. Large installation pretreatment can include media filters to remove suspended particles; ion exchange softening or antiscalant to remove hardness; temperature and pH adjustment to maintain efficiency; acid to prevent scaling and membrane damage; activated carbon or bisulfite to remove chlorine (postdisinfection may be required); and cartridge (micro) filters to remove some dissolved particles and any remaining suspended particles.

Maintenance - Monitor rejection percentage to ensure contaminant removal below SMCL. Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Use of monitoring equations to track membrane performance is recommended. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove fouling and scaling. The system is flushed and returned to service. $NaHSO_3$ is a typical caustic cleaner. RO stages are cleaned sequentially. Frequency of membrane replacement dependent on raw water characteristics, pretreatment, and maintenance.

Waste Disposal - Pretreatment waste streams, concentrate flows, and spent filters and membrane elements all require approved disposal.

Advantages -

! Produces highest water quality.

! Can effectively treat wide range of dissolved salts and minerals, turbidity, health and aesthetic contaminants, and certain organics; some highly-maintained units are capable of treating biological contaminants.

! Low pressure (<100 psi), compact, self-contained, single membrane units are available for small installations.

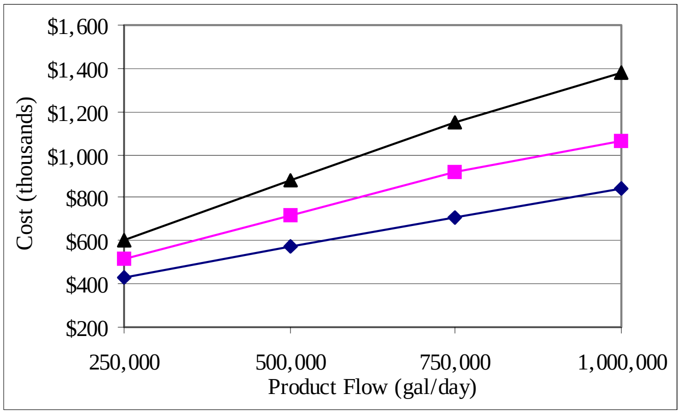
Disadvantages -

! Relatively expensive to install and operate (however NF membranes and operations are less than RO).

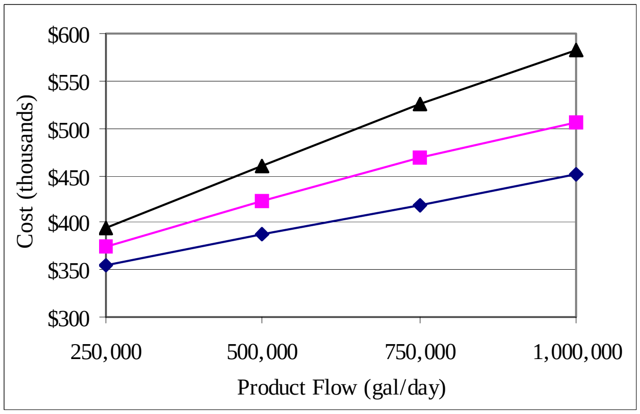
! Frequent membrane monitoring and maintenance; monitoring of rejection percentage for contaminant removal.

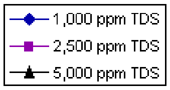
! Pressure, temperature, and pH requirements to meet membrane tolerances. May be chemically sensitive.

BAT Equipment Cost*



BAT Annual O&M Cost*





*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3B. Electrodialysis Reversal:
Process - EDR is an electrochemical process in which ions migrate through ion-selective semipermeable membranes as a result of their attraction to two electrically charged membrane surface. A typical EDR system includes a membrane stack with a number of cell pairs, each consisting of a cation transfer membrane, a demineralized flow spacer, an anion transfer membrane, and a concentrate flow spacer. Electrode compartments are at opposite ends of the stack. The influent feed water (chemically treated to prevent precipitation) and concentrated reject flow in parallel across the membranes and through the demineralized and concentrate flow spacers, respectively. The electrodes are continually flushed to reduce fouling or scaling. Careful consideration of flush feed water is required. Typically, the membranes are cation- or anion-exchange resins cast in sheet form; the spacers are HDPE; and the electrodes are inert metal. EDR stacks are tank contained and often staged. Membrane selection is based on careful review of raw water characteristics. A single-stage EDR system usually removes 50 percent of the TDS; therefore, for water with more than 1000 mg/L TDS, blending with higher quality water or a second stage is required to meet 500 mg/L TDS.

Electrodialysis Reversal (EDR) uses the technique of regularly reversing the polarity of the electrodes, thereby freeing accumulated ions on the membrane surface. This process requires additional plumbing and electrical controls, but increases membrane life, does not require added chemicals, and eases cleaning.

Pretreatment - Guidelines are available on accepted limits on pH, organics, turbidity, and other raw water characteristics. Typically requires chemical feed to prevent scaling, acid addition for pH adjustment, and a cartridge filter for prefiltration.

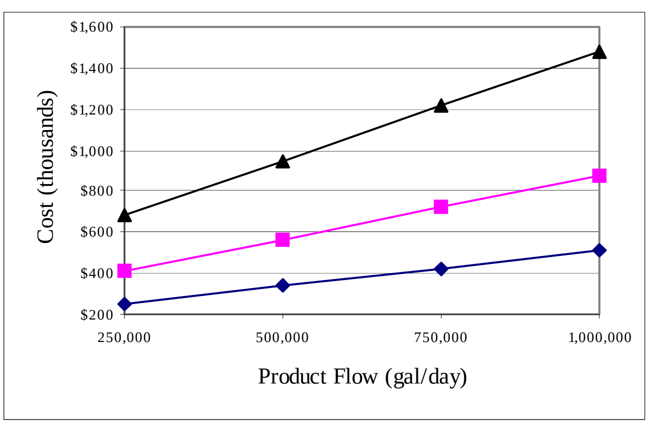
Maintenance - EDR membranes are durable, can tolerate pH from 1 - 10, and temperatures to 115°F for cleaning. They can be removed from the unit and scrubbed. Solids can be washed off by turning the power off and letting water circulate through the stack. Electrode washes flush out byproducts of electrode reaction. The byproducts are hydrogen, formed in the cathode space, and oxygen and chlorine gas, formed in the anode spacer. If the chlorine is not removed, toxic chlorine gas may form. Depending on raw water characteristics and TDS concentration, the membranes will require regular maintenance or replacement. EDR requires system flushes at high volume/low pressure; EDR requires reversing the polarity. Flushing is continuously required to clean electrodes. If utilized, pretreatment filter replacement and backwashing will be required. The EDR stackmust be disassembled, mechanically cleaned, and reassembled at regular intervals.

Waste Disposal - Highly concentrated reject flows, electrode cleaning flows, and spent membranes require approved disposal. Pretreatment processes and spent materials also require approved disposal.

Advantages -
! Low pressure requirements; typically quieter than RO.
! Long membrane life expectancy; EDR extends membrane life and reduces maintenance.

Disadvantages -
! EDR can operate without fouling or scaling, or chemical addition; suitable for higher TDS sources.
! Not suitable for high levels of Fe and Mn, H_2S, chlorine, or hardness.
! Limited current density; current leakage; back diffusion.
! At 50% rejection of TDS per pass, process is limited to water with 3000 mg/L TDS or less.

BAT Equipment Cost*



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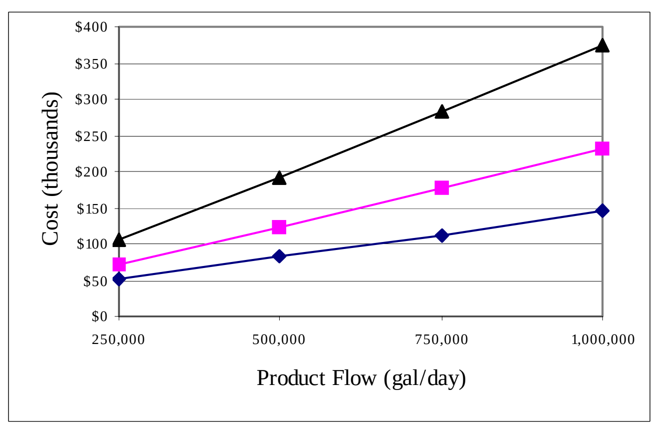

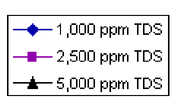

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